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Description

Circuit arrangement for EMC interference suppression for a direct current motor and a switching module

The invention is based on a circuit arrangement for EMC interference suppression for a direct current motor, with an attenuation element being connected in the supply line of the direct current motor and a switching module with an attenuation element according to the generic type of the independent claims 1 and 10.

It is already known for example in the case of a direct current (DC) motor, the rotors of which are supplied with current via brushes, that the sparking that results at the collector has to be suppressed or at least attenuated such that the resulting interfering radiation is harmless. This interference suppression to achieve electromagnetic compatibility - hereafter abbreviated to EMC interference suppression - is achieved by means of an attenuation element, which generally comprises a number of electronic components. For example two Y-capacitors are connected in series in the two supply lines towards the motor housing with two paralleling reactors, to increase the high frequency resistance. Sparking can be attenuated using this measure but its use of four components means that it is relatively complex and requires significant additional integration space, which is not available in the case of many applications or significantly restricts the design.

It is also known that EMC ferrites can be used to decouple line-conducted high-frequency signals, in particular high-frequency interference signals, as can occur for example in

the cable connections between a computer and a monitor, printer, data lines, etc. Such ferrites are marketed for example by the company Würth Elektronik or Vacuumschmelze and are available in different forms. Such attenuation elements are however only provided for use in computer and data lines and can only transmit a direct current limited to several amperes.

The object of the invention is to create a circuit arrangement and a switching module with a simplified and more economical attenuation element. This object is achieved with the features of the independent claims 1 and 10.

In contrast to the known prior art, with the claimed circuit arrangement and switching module it is proposed that a ferrite material should be used as the attenuation element. Such a component can generally be obtained at lower cost than the four components generally used for EMC interference suppression. Also it can be integrated more easily and faster, so the production costs for the DC motor are more favorable. It is deemed particularly advantageous that because of its structural and physical characteristics the ferrite material of the attenuation element is effective across a wider band than a conventional attenuation element, so that it is possible in particular to attenuate even high current peaks with high frequencies more effectively.

The measures listed in the dependent claims define advantageous developments and improvements of the circuit arrangement and switching module specified in the independent claims 1 and 11. It is deemed particularly advantageous that the attenuation element has a common mode ferrite. This material is designed particularly for the attenuation of high-

frequency interference signals, caused by the sparking of the DC motor.

Optimum EMC interference suppression is achieved when the attenuation element is disposed as close as possible to the DC motor and therefore the interference source. The resulting interference signals are then attenuated directly without being able to inject themselves into adjacent lines or circuit elements.

In a particularly advantageous solution the attenuation element is disposed directly on a printed circuit used to control the DC motor. The attenuation element can then be pre-produced together with other electronic components, required for example to control the DC motor.

Further miniaturization can be achieved if the attenuation element is configured as an SMD circuit, giving a particularly small design.

It also appears advantageous to configure the printed circuit such that it is also possible to insert the attenuation element later. As EMC interference suppression is not necessary for all motor types or applications, the attenuation element can also be integrated later. It is then particularly favorable if a standard printed circuit can still be used.

The attenuation element is configured particularly to suppress or attenuate the interference signals due to sparking resulting at the commutator of the DC motor. Injection into adjacent lines or functional interference to adjacent circuit elements can thus be effectively suppressed.

A particularly advantageous application of the claimed circuit arrangement relates to DC motors required to drive a unit or auxiliary generating set in a motor vehicle. These are particularly the type of DC motor required for transmission control, windshield wipers, a window closing system, a seat adjuster, etc.

An exemplary embodiment of the invention is described in more detail in the description that follows and illustrated in the drawings, in which:

Figure 1 shows a schematic illustration of a circuit diagram of a DC motor with a conventional attenuation element,

Figure 2 shows a schematic illustration of a circuit diagram of a DC motor with a claimed attenuation element,

Figure 3 shows a claimed embodiment of the attenuation element,

Figure 4 shows a first diagram with two interference voltage graphs and

Figure 5 shows a second diagram with three interference voltage graphs.

For a clearer understanding of the invention it is first explained with reference to figure 1 how the interference signals resulting due to sparking were suppressed or attenuated until now in a DC motor. The schematic illustration in figure 1 shows a DC motor 1, with a rotor 2 disposed in a housing 5, having a number of current windings that are supplied individually and being configured to be able to

rotate in a static magnetic field. Current is supplied to the rotor 2 via a commutator, which supplies the current windings of the rotor 2 with a constant or pulsed direct current by means of two brushes 3 disposed opposite each other. Each individual current winding of the rotor 2 is connected to two contact surfaces of the commutator in a paired manner, across which the brushes 3 pass. As the brushes 3 pass over to adjacent contact surfaces, unwanted sparking occurs, emitting interference signals in the high-frequency range in particular, which are for example transmitted to adjacent power lines and can interfere sensitively with electronic circuit components. This interfering radiation, referred to as EMC interference, is generally attenuated using an L/C element, generally comprising two capacitors C and two interference suppression coils L. As shown in figure 1, the two capacitors C, each for example 10nF, are connected in a Y-circuit between a line 4 and the housing 5 respectively, as close as possible to the brushes 3. An interference suppression coil L, with 7μH for example, is connected respectively to the lines 4. This L/C element should if possible be integrated into the housing, as interference suppression close to the interference source is the most effective.

For direct current this L/C element is low-resistance, while for steeply rising and high-frequency signals it has a relatively high resistance effect, as will be explained later. The DC motor 1 is connected via the lines 4 to a control circuit for controlling engine speed and torque, said control circuit frequently being located on a printed circuit 6 or PCB (printed circuit board). If the space situation permits, the PCB 6 can be disposed on or in the housing 5.

Figure 2 shows a schematic illustration of an exemplary embodiment of the invention. Instead of the L/C element, an attenuation element 7 is now connected upstream from the DC motor 1 described above, said attenuation element 7 being configured with a ferrite, in particular a common mode ferrite 9 (also referred to as a common mode or CM choke). Such ferrites generally comprise a number of layers or a sintered material, to achieve the highest possible impedance. To this end the two lines 4 are wound round the common mode ferrite 9 such that their magnetic fields mutually compensate each other. According to the known prior art common mode ferrites are only recommended for decoupling line-conducted interference in the high-frequency range. They are commercially available for different applications as an integrable component, e.g. as an SMD component, to facilitate assembly on a printed circuit. These components are typically used for measuring signal sensors, monitor lines, printer and mouse cables, data transmission lines, etc. The ferrites are available as block cores, ribbon cable ferrites, ferrite sleeves, ferrite rings, ferrite beads and ferrite bridges.

With the claimed exemplary embodiment however it is proposed according to figure 2 that such a common mode ferrite 9 be modified such that the attenuation element 7 can be used to suppress the interference of the DC motor 7, in particular to suppress its sparking. To this end a circuit arrangement is proposed, in which the attenuation element 7 can be integrated on a correspondingly prepared PCB 6 close to or if possible in the housing 5 of the DC motor 1, i.e. in proximity to the brushes 3.

In a preferred embodiment of the invention, the attenuation element 7 is configured for example as an SMD (surface mounted device) component and only assembled on the PCB 6 if required.

The PCB 6 is preferably configured such that it can be built together with the housing 5 of the DC motor 1 as a compact switching module in a shared housing. The PCB 6 also includes a control circuit, configured with a PWM (pulse width modulation) circuit for controlling the speed, torque and/or path of the DC motor 1. Such switching modules 10 can then be used for example in a motor vehicle for controlling different units and auxiliary generating sets such as windshield wipers, window closing systems, seat adjusters and/or for transmission control. In the last instance in particular the attenuation element 7 must be designed for very high peak currents, for example up to 40A. With the commercially available common mode ferrites 9 the peak currents are generally only a few amperes, so a corresponding modification is required in order to be able to achieve the required attenuation measures even with very large currents.

It is also advantageous if the attenuation element 7 and common mode ferrite 9 can be configured significantly smaller than is the case with the conventional L/C element. This means that less space is required so the housing 5 of the DC motor 1 can also be configured correspondingly smaller and more economically. Also the attenuation can be designed to be more effective and over a wider band, as shown below with reference to comparison diagrams.

Figure 3 shows a circuit diagram for the attenuation element 7, which is configured as a component with at least two input and two output terminals. It has a common mode ferrite 9,

around which the two power lines are wound such that the interference levels of the two currents I_{COM} mutually compensate each other. For steep current edges and high-frequency currents or voltages this attenuation element 7 is high resistance, while for direct current it is low resistance, so that the direct current can flow practically unimpeded to the DC motor 1.

The mode of operation of the claimed circuit arrangement is described in more detail with reference to figures 4 and 5. Figure 4 shows a first diagram, in which the signal frequency in Hz is shown on the x-axis and the amplitude (level in dBµV) is shown on the y-axis. The graphs shown represent individual instances for a specific DC motor 1. The segments of the graph a (thin line) show the sparking of the DC motor 1 with reference to a measurement protocol, when there is no EMC interference suppression. It can be seen here that the interfering radiation is particularly high at low frequencies in particular, drops a little as the frequency increases and rises again in the frequency range 6 to approx. 120 MHz.

In contrast the segments of the graph b (thick line) show the instance when the same DC motor 1 is connected to the claimed attenuation element 7. With this exemplary configuration of the common mode ferrite 9 there is no evident significant difference compared with the graph a in the lower frequency range up to approx. 2 MHz. At higher frequencies from approx. 6 MHz the interference level of the graph b is however significantly reduced. While the interference level of the graph a shows a level between approx. 30 and 50 dBµV, the level for the graph b is only in a range from approx. 10 to 30 dBµV. The same can be seen in the frequency range 25 to 120 MHz. This is a significant reduction in the interference level

compared with the instance without interference suppression in graph a.

Figure 5 shows a second diagram with a similar scale, as already described in respect of figure 4. Here however the frequency range on the x-axis is considered in the interval from approx. 5 MHz to approx. 120 MHz. The diagram shows three different measurement graphs c, d, e. The segments of the graph c show the instance when the DC motor 1 is connected without attenuation element 7. The segments of the graph d show the interference level pattern when the DC motor 1 was connected to a conventional L/C element with L = 7μH and C = 10nF. The segments of the graph e with a thick line show the instance when the DC motor 1 was connected to the claimed common mode ferrite 9. It can be seen from the graph segments in the four frequency ranges shown that the interference level for the graph e is generally lower than for graphs c and d. It is particularly clear that in the mean frequency range between 25 and 35 MHz the interference level of the graph e is significantly lower than for the graph d, which corresponds to assembly with the conventional L/C element. This frequency range can of course be displaced, if the attenuation element 7 has different dimensions.

A further advantage is that the structure with the common mode ferrite 9 can be significantly smaller than with the conventional L/C element, so that further structural advantages result, as already mentioned above.